農村工程項目綠色評價管理研究

STUDY ON EVALUATION GREEN PROJECT MANAGEMENT FOR RURAL ENGINEERING

福建農林大學
交通與土木工程學院
副教授

李 曉 娟*
Xiao-Juan Li

摘 要

近年來，出現了環保可持續建築建設的指數增長。環保意識的提高促使建築項目管理人員“走向綠色”，並對綠色建築的項目交付進行了多項研究。然而，目前對於農村工程項目管理的研究還不夠全面，工程項目管理的決策對工程項目的環境績效有著重要的影響。由於綠色項目在氣候變化的不利影響日益嚴重的世界中具有顯著的效益，因此得到了廣泛的推廣。在此背景下，本文提出了基於層次分析法和熵權法的灰色關聯理論來確定農村工程綠色項目管理評價指標的權重。 應用實例表明，將該方法應用於農村工程項目綠色評價是可行的。

關鍵詞：農村工程項目、綠色評價、評價體系、環境績效。

* 通訊作者，福建農林大學交通與土木工程學院副教授，
福建省福州市倉山區上下店路 15 號，xiaojuanli@fafu.edu.cn

STUDY ON EVALUATION GREEN PROJECT MANAGEMENT FOR RURAL ENGINEERING

Xiao-Juan Li*
College of Transportation and Civil Engineering,
agriculture and forestry university

ABSTRACT

In recent years, there has been an exponential growth of environmental sustainable buildings construction. Greater environmental awareness had induced the managers of building projects to "go green," and several studies have been conducted on the project delivery of green building. However, there is no comprehensive study that explores the important project management, whose decisions can significantly affect the environmental performance of building projects. Due to their pronounced benefits in a world of ever increasing climate change detrimental effects, green projects have been widely promoted. Moreover, their evaluation seems to be taking a snail pace. Against this backdrop, we propose a Gray correlation theory based on AHP and entropy methods to determine the weights of green project management evaluation index for rural engineering. The applied cases suggest that it is feasible to apply this method to green project management evaluation.

Keywords: Rural engineering project, Green evaluation, Evaluation system, Environmental performance.

Li, X.J*. (2020). "Study on Evaluation Green Project Management for rural Engineering." *Journal of Taiwan Agricultural Engineering,* 66(3), 21-30. https://doi.org/10.29974/JTAE.202009_66(3).0003

1. Introduction

Because of the negative environmental impacts of traditional building, green building has attracted more attention in recent years, and an increasing number of studies have been conducted on the project delivery of green building.

Green Project Management (also referred as green engineering project management - GEPM) is the inevitable choice of an ecological sustainable economy. It entails a full range of planned construction projects from concept to completion, control and coordination, in order to meet people's requirements, the project required quality standards on the basis of ecological indicators, and within a prescribed period at the least costs. GEPM objectives can be achieved by the use of green technologies, energy conservation, pollution control, and scientific treatment of construction waste. The core of green management is green management theory, which is transforming project management to new heights. Compared with traditional management methods, key features include seeing projects through an environmental lens (*i.e.* having less impacts on the environment), save resources, and evaluate engineering project management activities from the view of harmonious development. In exploring green management practices for sustainable construction, Robichaud [4] showed that such practices could contribute significantly to a sustainable construction project while delivering it at acceptable cost constraints.

The basic principles of green engineering project management implementation as outlined by Teo [5] are: i) Always adhere to the energy saving, environmental protection in the important position in the construction project management, and implement the related laws and regulations, mandatory standards and energy conservation and emission reduction policies about the national construction projects, and pay much attention to environmental quality, and figure out management objectives, and put appropriate manpower, financial and material resources to ensure the realization of environmental management objectives. ii) Adhere to local conditions, multi-faceted development of construction project management methods, and the construction projects and local resources, environmental conditions are organically combined to innovate the system mechanism of the construction project management. Finally, adhere to the combination of economic, social and ecological benefits, and correctly view the short-term benefits and long-term benefits to achieve business development and good social benefits of a win-win. These are summarized in Fig. 1.

How to effectively implement green management project remains a complicated task since in several regions, a framework for such projects is not available [1]. It is therefore imperative to put forth means of successfully drawing a GEPM. Besides, the above impediments the authors found project costs to be an utmost barrier and based on surveys proposed that governments should provide incentives. The reader is referred to the above paper for detailed proposed solutions. Qian *et al.* [3] proposed a weighted grey correlation analysis based on the analytic hierarchy process (AHP). They also provided GEPM evaluation steps and specific management measures in order to realize the significance of greening.

Lauren[4] suggested sustainable green projects management on concrete to manage resistance characteristics and comprehensive evaluation. A general observation is, studies on green project management factors are vast, while green management evaluation studies are relatively sparse. Therefore, this study aims to explore effective evaluation measures for green management projects. Present methods include fuzzy evaluation method [9], analytic hierarchy process [6] and principal component analysis method [8]. Despite their wide adoption, these methods are complex. Moreover, in this study we analyze

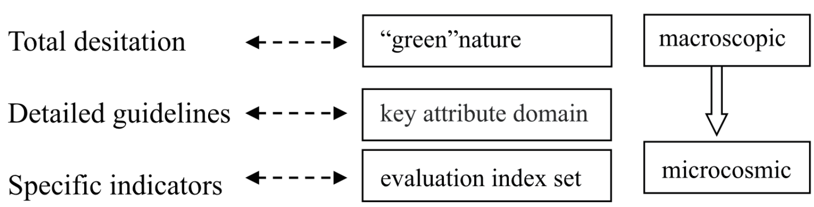

Fig. 1. The overall architecture of green evaluation index system of project management

JOURNAL OF TAIWAN AGRICULTURAL ENGINEERING
VOL. 66, NO. 3, SEPTEMBER 2020
DOI - 10.29974/JTAE.202009_66(3).0003

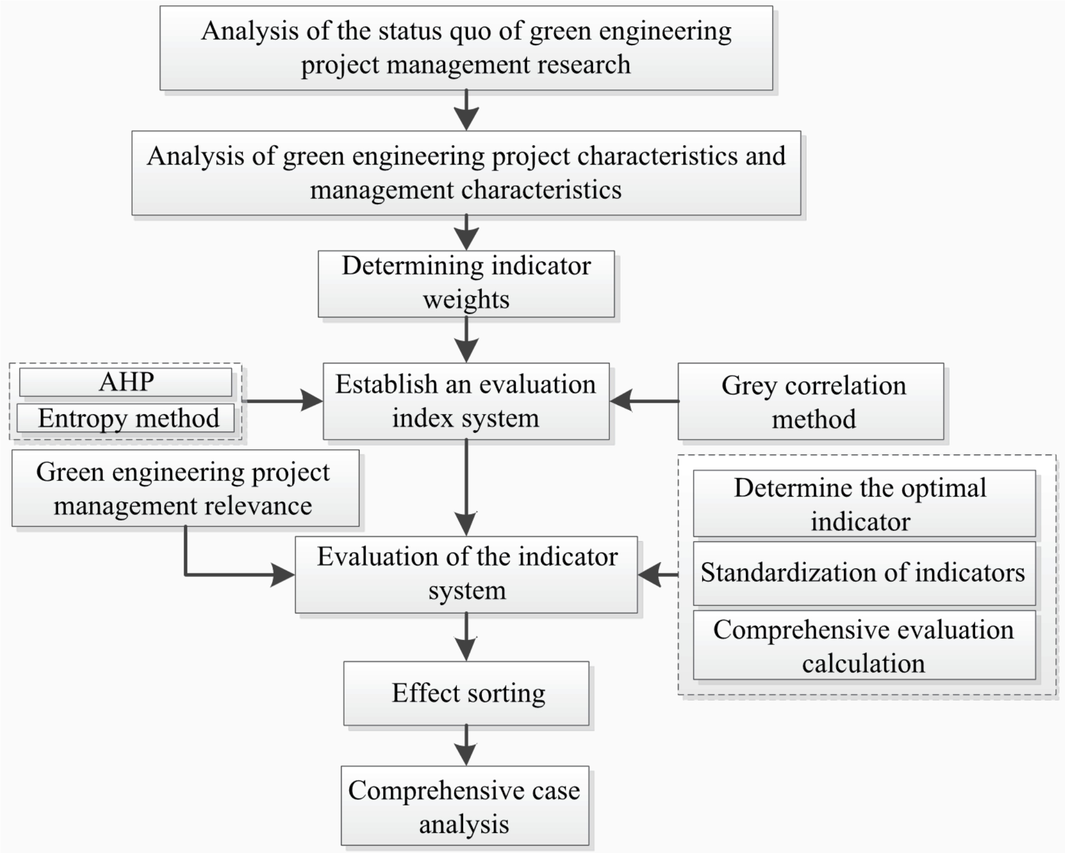

Fig. 2. **performance evaluation method for green rural project management**

the characteristics of green project and its management characteristics, and establish the evaluation system of green project. AHP and entropy methods are used to determine the weight of green project management evaluation index. The Gray correlation theory is used to evaluate the green management of engineering projects, and the results are ranked to solve the challenges caused by other methods and is suitable for green project management evaluation. Case studies are then provided to show suitability of the proposed method. Performance evaluation method for green project management is shown in Fig. 2.

2. Research Method

2.1 Establishing a Project Management Evaluation Index

The establishment of the index system should follow these principles. And index should be simplified. Independent should be representative and different, feasible, and in accord with the objective level. According to the above principles and the literature [2], in the development of a design evaluation index set, the screening process should be designed and combine it with earlier research results. By communicating with nine project management experts, through the use of Delphi method, experience and feelings are fully collectted. Hence, the green project management evaluation index system will be based on the feedback information obtained as illustrated by Fig. 3. Evaluation index system of agricultural engineering project include the nature of resource, the nature of management, the nature of environment, the nature of technology and the nature of economy. The nature of resource include material, the use of clean energy, unilization rate, equipments, energy efficiency ratio, the use of renewable energy and energy consumption. The nature of management include management participation in staff training, environmental of investment and green plan. The nature of environment include air, water, noise and waster. The nature of technology include the

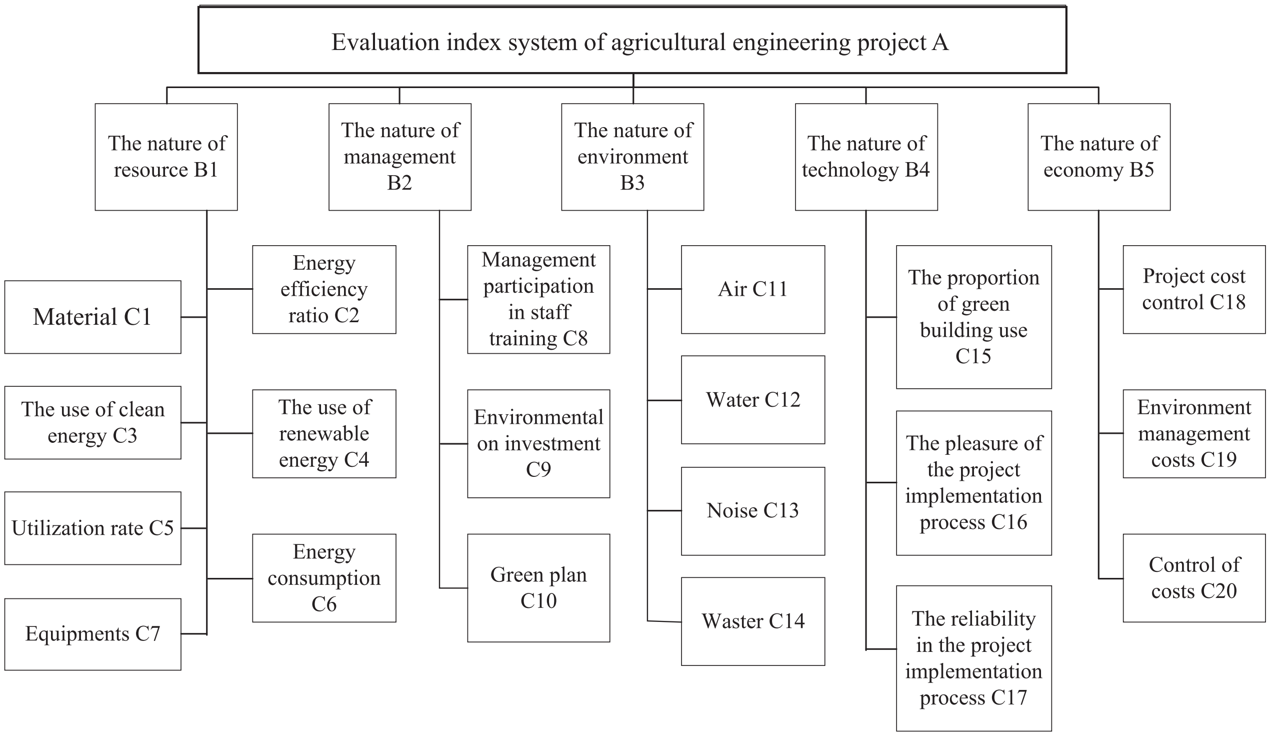

Fig. 3. The Evaluation index system of agricultural engineering project management

proportion of green building use, the pleasure of the project implementation process and the reliability in the project implementation process. The nature of economy include project cost control, environment management costs and control of costs.

2.2 Definition and calculation of index weights

The term “weight” is used in decision making, and the status of each index (criterion) is different in decision making. The difference is mainly reflected in theses aspects: the degree of attention the decision-makers given to each index is different; the role of index in the decision-making is different. That is to say, during decision-making, the amount of decision-makers information transmitted by each index is different. And the reliability of the evaluation value of each index is different. Therefore, in the multi-index decision-making, it is often necessary to assign weights to each index to describe these differences. The weight of the index is not only related to the subjective evaluation of the importance of the index, but also to the degree of reliability of the amount of information and index values transmitted by the feasible scheme to the decision maker[7]. If ω_{i_1}, ω_{i_2}, ω_{i_3}, represent the weights of the three aspects respectively, there is

$$\omega_i = f(\omega_{i_1}, \omega_{i_2}, \omega_{i_3}) i = 1, 2, \cdots, n \text{ ....(1)}$$

In the formula: ω_{i_1} is given by the decision maker in advance or determined by the AHP method and other subjective. Hence, it is referred to as subjective weight. It reflects the decision-maker’s knowledge structure, ability and psychological and social, environmental background, etc.; ω_{i_2} reflects the information amount, which is transmitted to the decision-makers by each index, under the condition of decision determined, and it is sensitive to the program and evaluation results. The greater the difference of the evaluation value of the index, the greater the comparison effect of the index on the scheme; ω_{i_3} represents the reliability of the evaluation value, and the higher the degree, the larger it is.

Considering the weight of these three aspects, the weight of the first index is defined as:

$$\omega_i = \omega_{i_1}\omega_{i_2}\omega_{i_3} / \sum_{i=1}^{n} \omega_{i_1}\omega_{i_2}\omega_{i_3},\ \ i = 1,2,\ldots,n \text{ ....(2)}$$

According to the characteristics of the index system, the objective weight is determined by the entropy method, and the subjective weight is determined by the AHP method. Assuming the reliability weight is 1.

2.3 Entropy method to determine the objective weight

Suppose there are m evaluation indexes and n evaluation objects (program). If there are standardized multi-program, multi-index evaluation matrix:

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (3)$$

Definition 1: Entropy of evaluation index. In the evaluation problems, including m evaluation indexes and n evaluation objects, the entropy of the i-th evaluation index is defined as

$$H_i=-k\sum_{i=1}^{n} f_{ij}\ln f_{ij},\ \ i=1,2,\ldots,m \quad (4)$$

In the formula: $f_{ij}=\frac{r_{ij}}{\sum_{i=0}^{n} r_{ij}}$; $k=\frac{1}{\ln n}$ can choose k and make $0\le H_i\le 1$.

Definition 2: Entropy weight of the evaluation index. In the evaluation problem, the entropy weight of the i-th evaluation index ω_i is defined as

$$\omega_i=\frac{1-H_i}{m-\sum_{i=0}^{n} H_i} \quad (5)$$

2.4 AHP method to determine the subjective weights

(1) Construct judgment matrix. Suppose that the set of judgment index is: $T=(t_1,t_2,\ldots,t_n)$. First, according to the impact , made by each index of the achieving purposes, the experts compare the importance of each evaluation in pairs, and assign it a definite value, then we use a_{ij} represent the importance of t_i to t_j. According to the research results by several scientists, the qualitative difference between the information level is 7 ± 2, so we adopt the scaling rules of 1 to 9, as shown in Tab. 1. The judgment matrix has the following properties:

$$\alpha_{ij}>0, \alpha_{ij}=1/\alpha_{ij} \quad (6)$$

(2) Calculation of decision weight value. According to the subjection relationship of the upper and lower layer elements determined by the hierarchical structure, we can create pairwise comparison matrices. Creating judgment matrix according to the rule of the scaling in Tab. 1, in practical application, we usually adopt approximation solution, such as power method, root method and product method, to calculate the weight. In this study, we adopt the root method to simplify weight calculation process. The weight calculation of the layer index to the upper layer is shown below:

Multiplication of elements in the judgement matrix

$$M_i=\prod_{i=1}^{n} a_{ij} \quad (7)$$

Calculate the n-th root of the M_i

$$\overline{W_i}=\sqrt[n]{M_i} \quad (8)$$

Make the vector $\overline{W_i}$ be normalized.

$$\overline{W_i}=\overline{W_i}\Big/\sum_{i=1}^{n}\overline{W_i} \quad (9)$$

If the normalized values of the vector $\overline{W_i}$ satisfy the consistency test, it is the weight of the layer index on the upper layer.

Tab. 1. The meaning of the judgment matrix scaling a_{ij}

Scaling	Meaning
1	Two factors compared, factor *i* has the same “same” importance as factor j
3	Two factors compared, factor *i* has a “slightly” importance with factor j
5	Two factors compared, factor *i* and factor *j* have a “significant” importance
7	Two factors compared, factor *i* and factor *j* have a “very” importance
9	Two factors compared, factor *i* and factor *j* have “extreme” importance
2，4，6，8	The median above two adjacent judgments

Consistency test. The difference caused by people's understanding of objective things may affect the judgment validity. Therefore, to avoid too much deviation, thus affect calculation there is a need to conduct the consistency test of the judgment matrix. This may be judged by the index CR. When CR < 0.1, consistency test of the judgment matrix is good. If CR > 0.1, the judgment matrix needs some adjustments, to meet the requirements of the consistency condition.

$$CI = \frac{(\lambda_{max} - n)}{n-1} \quad \text{.......... (10.1)}$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad \text{.......... (10.2)}$$

In the formula: λ_{max} is the maximum in the judgment matrix; n is the matrix order; A represents the judgment matrix; W is the weight vector; $(AW)_i$ represents the i-th element of the composite matrix after multiplication; RI is the correction coefficient, which changes with the value of the number n, and the specific value is shown in Tab. 2.

Tab. 2. Average random consistency index (*RI*)

Matrix order	1~2	3	4	5	6	7	8	9
RI	0	0.58	0.96	1.12	1.24	1.32	1.41	1.45

NB: when $n = 1$, and $n = 2$, there is always a complete consistency, and no need to test

2.5 Evaluation of Correlative Degree of Green Project Management

In most cases, the comprehensive evaluation of things is to study the problem of multi-object sorting, which is determine the optimal order among each evaluation object. Gray comprehensive evaluation is mainly based on the following models:

$$R = E \times W \quad \text{.......... (11)}$$

In the formula: $R = [r_1, r_2, \cdots, r_m]^T$ is the vector of the comprehensive evaluation results for m evaluated subjects; $W = [w_1, w_2, \cdots, w_m]^T$ is the weight distribution vector for n evaluation indexes, in $\sum_{j=1}^{n} w_j = 1$, E is the judgment matrix of each index.

$$E = \begin{bmatrix} \xi_1(1) & \xi_1(2) & \cdots & \xi_1(n) \\ \xi_2(1) & \xi_2(2) & \cdots & \xi_2(n) \\ \vdots & \vdots & & \vdots \\ \xi_m(1) & \xi_m(2) & \cdots & \xi_m(n) \end{bmatrix} \quad \text{.......... (12)}$$

In the formula: $\zeta_i(k)$ is the correction coefficient of the k-th index and k-th optimal index in i-th program. Then it is ranked based on R.

2.6 Determine the optimal index set (F^*)

Supposing $F^* = [j_1^*, j_2^*, \cdots, j_n^*]$, in which j_k^*(k = $1, 2, \cdots, n$) is the optimal value of the k-th index. The optimal value is the best in all programs (if a certain index takes large value as well, the maximum value of the index in each scheme is taken, and if the small value is good, the minimum value in each scheme is taken), and it also is the optimal value recognized by evaluators. However, in determining the optimal value, we should consider both the advanced and the feasibility. If the optimal value is very high and couldn't be achieved, the valued results cannot be accepted.

2.7 Standardization of index values

Because usually there are different dimensions and orders of magnitude in the evaluation indexes, they cannot be compared directly. In order to ensure the reliability of the results, we need to standardize the original index.

Supposing the change interval of the k-th index is $[j_{k1}, j_{k2}]$, in which j_{k1} is the minimum of the k-th index in all programs, and the j_{k2} is the maximum of the k-th index in all programs. Then the original value can be changed into dimensionless value $C_k^i \in (1, 0)$ by the calculating j_k^i with formula (13).

$$C_k^i = \frac{j_k^i - j_{k1}}{j_{k2} - j_k^i} = 1, 2, \ldots, m;\ k = 1, 2, \ldots, n \quad \text{.......... (13)}$$

Then get C matrix

$$C = \begin{bmatrix} C_1^* & C_1^* & \cdots & C_1^* \\ C_1^1 & C_2^1 & \cdots & C_n^1 \\ \vdots & \vdots & & \vdots \\ C_1^m & C_2^m & \cdots & C_n^m \end{bmatrix} \quad \text{.......... (14)}$$

JOURNAL OF TAIWAN AGRICULTURAL ENGINEERING
VOL. 66, NO. 3, SEPTEMBER 2020
DOI - 10.29974/JTAE.202009_66(3).0003

2.8 Calculate the results of the comprehensive evaluation

According to the gray system theory, the {C*}= $\left[C_1^i, C_2^i, \ldots, C_n^i\right]$ is considered as the comparison sequence. Then the correlation coefficient $\zeta_i(k)$ of the k-th index and the k-th optimal index of the i-th scheme is obtained separately by the correlation analysis method.

$$\zeta_i(k)=\frac{\min_i \min_k \left|C_k^*-C_k^i\right|+\rho \max_i \max_k \left|C_k^*-C_k^i\right|}{\left|C_k^*-C_k^i\right|+\rho \max_i \max_k \left|C_k^*-C_k^i\right|} \quad ..(15)$$

In the formula: $\rho \in [0,1]$, generally, $\rho = 0.5$.

The E can be calculated by $\zeta(k)$, so the result of comprehensive evaluation is $R = E \times W$, that is

$$r_i=\sum_{k=1}^{n} w(k) \times \zeta_i(\mathrm{k}) \quad \ldots\ldots (16)$$

If correlation degree r_i is maximum, it indicates $\{C^i\}$ is closest to the optimal index $\{C^*\}$. That is to say the i-th program is superior to other programs, and the order of the schemes can be sorted accordingly.

3. Case study

3.1 Survey

Sample surveys on 4 companies in Fujian province were conducted on engineering rural projects, and were evaluated on site, and arranged based on merits and demerits using the evaluation index system in Fig. 1. These companies include: Chang Yuan Construction Engineering Co., Ltd., Shi Lian Construction Engineering Co., Ltd., Hongda Construction Engineering Co., Ltd., China Construction Engineering Bureau (numbered 1, 2, 3, 4, respectively). The final scores can be seen in Tab. 3 and Tab. 4.

Tab. 3. Experts scoring C1-C10

Construction site number	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	88	86	90	94	80	85	70	85	86	88
2	85	88	86	87	78	90	85	86	88	94
3	80	85	84	84	88	86	87	90	80	85
4	90	86	84	86	88	85	87	86	87	78

Tab. 4. Experts scoring C11-C20

Construction site number	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
1	89	82	84	85	89	90	84	86	85	85
2	82	78	86	84	83	82	81	86	74	80
3	84	86	87	85	82	85	88	86	88	90
4	88	85	84	83	82	87	88	90	85	86

3.2 Entropy Method to Determine Objective Weights

For the first level index, adopting expert investigation determines its weight. By questionnaire investigation, the weights are calculated for (0.3, 0.1, 0.3, 0.2, 0.1). For the second level index, its objective weight is determined through entropy method, and the judgment matrix, R_1, of the second level index can be determined by Tab. 3.

$$R_1=\begin{bmatrix} 88 & 85 & 80 & 90 \\ 86 & 88 & 85 & 86 \\ 90 & 86 & 84 & 84 \\ 94 & 87 & 86 & 86 \\ 80 & 78 & 88 & 88 \\ 85 & 90 & 86 & 85 \\ 70 & 85 & 87 & 87 \end{bmatrix} \quad \ldots\ldots (17)$$

Divide matrix by 100，then calculate the entropy weights of the sequence form C1 to C7 according to formula (9) and the results are (0.140, 0.143, 0.144, 0.143, 0.142, 0.143, 0.145). Similarly, the entropy of other indexes is calculated and the results are (0.334, 0.332, 0.334), (0.248, 0.249, 0.251, 0.252), (0.332, 0.331, 0.337), (0.332, 0.332, 0.336). Therefore, the objective weights of all indexes calculated are (0.042, 0.043, 0.043, 0.043, 0.042, 0.043，0.044, 0.033, 0.033, 0.033, 0.075, 0.075, 0.076, 0.076, 0.066, 0.066, 0.067, 0.033, 0.033, 0.034).

3.3 AHP method determine the subjective weights

Based on Fig. 1 and the theory of AHP method, the corresponding judgment matrix is constructed for the second level indexes. The matrices are shown in Tab. 5 to Tab. 10.

Tab. 5. A-B judgment matrix

A	B1	B2	B3	B4	B5
B1	1	5	7	7	5
B2	5	1	3	2	1
B3	7	3	1	1	1/3
B4	7	2	1	1	1/3
B5	5	1	1/3	1/3	1

Tab. 6. B1-C judgment matrix

B1	C1	C2	C3	C4	C5	C6	C7
C1	1	1	3	3	3	1	4
C2	1	1	2	2	2	1	3
C3	3	2	1	1	1	1/3	1
C4	3	2	1	1	1	1/3	1
C5	3	2	1	1	1	1/3	1
C6	1	1	1/3	1/3	1/3	1	3
C7	4	3	1	1	1	3	1

Tab. 7. B2-C judgment matrix

B2	C8	C9	C10
C8	1	7	1/3
C9	7	1	1/8
C10	1/3	1/8	1

Tab. 8. B3-C judgment matrix

B3	C11	C12	C13	C14
C11	1	5	5	3
C12	5	1	1	1/3
C13	5	1	1	1/3
C14	3	1/3	1/3	1

Tab. 9. B4-C judgment matrix

B4	C15	C16	C17
C15	1	1	1/5
C16	1	1	1/5
C17	1/5	1/5	1

Tab. 10. B5-C judgment matrix

B5	C18	C19	C20
C18	1	5	5
C19	5	1	1
C20	5	1	1

Through the computations, the subjective weights of the indexes are; (0.136, 0.112, 0.048, 0.048, 0.047, 0.134, 0.044, 0.033，0.006, 0.071, 0.058, 0.010, 0.010, 0.026, 0.014, 0.014, 0.073, 0.084, 0.017, 0.017).

3.4 Green evaluation of agricultural engineering project management based on Gray correlation theory

According to formula (7), the grey correlation coefficient is calculated. For company 1, the minimum and maximum of two levels are $\min_i \min_k |X_0(k)-X_i(k)|=2$, $\max_i \max_k |X_0(k)-X_i(k)|=10$ respectively. Take ρ as 0.5, and the coefficients ξ of the Gray correlation are shown in Tab. 11, Tab. 12.

Tab. 11. The correlation coefficients, C1 to C10, of the evaluation indexes of green engineering project management

Construction site number	C1	C2	C3	C3	C5	C6	C7	C8	C9	C10
1	0.81	0.81	1	1	0.52	0.63	0.33	0.63	0.81	1
2	0.63	1	0.68	0.56	0.46	1	0.81	0.68	1	0.68
3	0.46	0.74	0.59	0.52	1	0.68	1	1	0.52	0.74
4	1	0.81	0.59	0.52	1	0.63	1	0.68	0.89	0.46

Tab. 12. The correlation coefficients C11 to C20, of the evaluation indexes of green engineering project management

Construction site number	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
1	1	0.68	0.74	1	1	1	0.68	0.68	0.74	0.63
2	0.56	0.52	0.89	0.89	0.59	0.52	0.55	0.55	0.38	0.42
3	0.63	1	1	1	0.55	0.63	1	0.68	1	1
4	0.89	0.89	0.74	0.81	0.55	0.74	1	1	0.74	0.68

3.5 Discussion

The degrees of the Gray correlation in the companies are r_1=0.773, r_2=0.710, r_3=0.732, r_4=0.802, the rank of which is $r_4 > r_1 > r_3 > r_2$.

Correlation degree r_4 is maximum, which indicates $\{C^4\}$ is closest to the optimal index $\{C^*\}$. That is to say that construction site 4 is superior to other programs, and the order of the schemes can be sorted accordingly. Therefore, the green rural project management of the 4-th company is recommended as the best plan, which is superior to others.

4. Conclusions

The primary contribution of this study is identifying a set of rural engineering project green management appraisals based on the AHP and Entropy methods. The AHP and Entropy methods were introduced into green engineering rural project management index weight, which has objectivity, and overcome subjectivity. The Gray theory was applied to the evaluation of green rural engineering project management and green engineering project management level, which determine its strengths and weaknesses. Our findings suggest combining these three methods to better solve the challenges of green engineering project management evaluation. Findings from these study will be further explored in future works, since conclusions are drawn on only a few cases to foster better management and evaluation strategies.

References

1. Hwang, B.G. and Tan, J.S., "Green building project management: obstacles and solutions for sustainable development," Sustainable Development, Vol. 20, pp. 335-349 Doi:10.1002/sd.492, 2012.
2. Nassar, N.K., "An integrated framework for evaluation of performance of construction projects," Paper presented at the PMI® Global Congress, North America, Orlando, FL. Newtown Square, PA, 2009.
3. Qian, L., Ma, J. and Zhang, Z., *et al.*, "A grey relational analysis based study on green degree evaluation of urban logistics," American Journal of Applied Mathematics. Vol. 2, pp.209-213, 2014.
4. Robichaud, L.B. and Anantatmula, V.S., "Greening Project Management Practices for Sustainable Construction," J Manage Eng. Vol. 27, pp. 48-57, Doi:10.1061/(ASCE)ME.1943-5479.0000030, 2011.
5. Teo, E.A., Chan, S.L. and Tan, P. H., "Empirical Investigation into Factors Affecting Exporting Construction Services in SMEs in Singapore," J Constr Eng Manage 2011. 2007, Vol. 133, pp. 582-591 Doi:10.1061/(ASCE)0733-9364(2007)133:8(582), 2011.
6. Wen, Y.L., "The analytic hierarchy process in project evaluation: An R&D case study in Taiwan Benchmarking," An International Journal, Vol. 10, pp. 445-456 Doi: doi:10.1108/14635770310495492, 2003.
7. Wu, Q. and Peng, C., "Comprehensive Benefit Evaluation of the Power Distribution Network Planning Project Based on Improved IAHP and Multi-Level Extension," Assessment Method Sustainability, Vol. 8, pp. 796, 2016.
8. Xue, H., Zhang, S. and Su, Y., *et al.*, "Capital Cost Optimization for Prefabrication: A Factor Analysis Evaluation Model Sustainability," Vol. 10, pp. 159, 2018.
9. Zhou, R. and Chan, A., "Using a fuzzy comprehensive evaluation method to determine product usability: A test case Work (Reading, Mass)," Vol. 56, pp. 21-29 Doi:10.3233/WOR-162473, 2016.

收稿日期：民國 109 年 01 月 15 日
修正日期：民國 109 年 02 月 11 日
接受日期：民國 109 年 03 月 13 日